Overview of Hydraulic Fracturing

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Upstream Technology
Having a new abundance of natural gas is changing the vision of our energy future.
What is hydraulic fracturing?

Hydraulic fracturing is a process used in nine out of ten natural gas wells in the United States, where millions of gallons of water, sand and chemicals are pumped underground to break apart the rock and release the gas or oil.
Hydraulic Fracturing

Hydraulic fracturing, or "fracing," involves the injection of more than a million gallons of water, sand and chemicals at high pressure down and across into horizontally drilled wells as far as 10,000 feet below the surface. The pressurized mixture causes the rock layer, in this case the Marcellus Shale, to crack. These fissures are held open by the sand particles so that natural gas from the shale can flow up the well.

http://www.propublica.org/special/hydraulic-fracturing-national
Hydraulic Fracturing – What is it?

- **Mixture of proppants and fluids pumped into reservoirs**
  - Sand, coated sand, man-made ceramic beads
  - Water, chemicals

- **Creates efficient paths for oil/gas to reach wellbores**
  - Enhances low (natural) reservoir permeability
  - Bypasses borehole damage from drilling

- **Frac treatments drive well designs**
  - Pressure ratings of wellhead, production casing, perforation plans, etc
  - Highly engineered: MRO + service company engineers, geoscientists, HES personnel, field supervision, etc
Hydraulic Fracturing
Definition

- Pumping a fluid and/or slurry into a formation at pressures and injection rates high enough to create, sustain or extend a fracture or crack.
First Hydraulic Fracturing Treatment

- Stanolind Oil
  Klepper No. 1 well
  July 1947

- Hugoton gas field,
  Grant County, Kansas

- Gasoline-based napalm gel with no proppant pumped into four limestone pay zones from 2340 to 2580 feet

- Well produced the same as nearby acidized wells
Hydraulic Fracturing – Why?

- **Key enabling technology**
  - Most US onshore gas plays are uneconomic without “fracing” (gas shales, oil shales, tight gas, coalbed methane)
  - Significant resources dependent upon “fracing”
    - NA shale and tight gas - 5211 tcf (868 bboe) (2007 NPC Study)
    - Bakken oil - 3.6 bbo (2008 USGS assessment)

- **MRO resources dependent upon “fracing”**
  - US shales (Bakken, Marcellus, Woodford, Haynesville)
    - Capex: $375 million (2010), $6.5 billion (project lives)
    - Resource potential > 325 mmboe
  - US tight gas (Piceance, East Texas, Oklahoma, Alaska)
    - Capex: $235 million (2010), $3.2 billion (project lives)
    - Resource potential > 150 mmboe
Production Flow Analysis

Natural Flow

Stimulated Flow
Hydraulic Fracturing Example

- Fracture Design and Production Prediction
- Post Fracturing Production
Statistics

- Statistics on application of Hydraulic Fracturing
  - 32 States with oil and gas production
    - 27 states making up 99.9% of US Oil & Gas development
  - % of new completions – 60-80% of all wells drilled in the next 10 years will require Hydraulic Fracturing. Hydraulic Fracturing is responsible for 30% of US recoverable oil and gas reserves for an addition of 7 billion bo and 600 trillion cf gas.
Frac Job (Early 2008 Bakken Well)

- 500 bbl ea. Frac Tanks (Freshwater storage)
- Sand Storage Bins (~250k lbs each)
- Blender (Mix Sand, Water, Chemicals)
- Frac Pumps (11 @ ~2000 HP ea.)
- Control Van
- Wellhead
- Suction/Discharge Manifold
“Zero spill” expectation
Fully drain all treatment, chemical, and water lines before rig-down
Proper well construction provides groundwater protection.
Water Sources

Water sourcing

- surface water
- fresh water wells
- municipal systems
- reuse of flowback
Storage and Treatment

Flowback and disposition options
- Temporary storage (tanks or lined pits)
- Treatment at MRO production facilities
- MRO-operated Class II disposal wells
- Commercial disposal wells
- Municipal or commercial treatment plants

Bakken Example
Water source: Municipal water system, fresh water well
Use: Slickwater, cross-linked fluids
Disposition: MRO Class II disposal well, commercial disposal well
Fracturing Fluids

The main fluid categories are:

- Gelled fluids, including linear or cross-linked gels
- Foamed gels
- Plain water and potassium chloride (KCl) water
- Acids
- Combination treatments (any combination of 2 or more of the aforementioned fluids).
What are fracturing fluids?

**Typical Shale Fracturing Mixture Makeup**

- 90% WATER
- 9.5% SAND
- 0.5% CHEMICAL ADDITIVES

**Typical Chemical Additives Used in Frac Water**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Purpose</th>
<th>Common application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>Helps dissolve minerals and initiate fissure in rock (pre-fracture)</td>
<td>Swimming pool cleaner</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>Allows a delayed breakdown of the gel polymer chains</td>
<td>Table salt</td>
</tr>
<tr>
<td>Polyacrylamide</td>
<td>Minimizes the friction between fluid and pipe</td>
<td>Water treatment, soil conditioner</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Automotive anti-freeze, deicer agent, household cleaners</td>
</tr>
<tr>
<td>Borate Salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Laundry detergent, hand soap, cosmetics</td>
</tr>
<tr>
<td>Sodium/Potassium Carbonate</td>
<td>Maintains effectiveness of other components, such as crosslinkers</td>
<td>Washing soda, detergent, soap, water softener, glass, ceramics</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water</td>
<td>Disinfectant, sterilization of medical and dental equipment</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>Thickens the water to suspend the sand</td>
<td>Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces</td>
</tr>
<tr>
<td>Citric Acid</td>
<td>Prevents precipitation of metal oxides</td>
<td>Food additive; food and beverages; lemon juice</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>Used to increase the viscosity of the fracture fluid</td>
<td>Glass cleaner, antiperspirant, hair coloring</td>
</tr>
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Source: DOE, GWPC; Modern Gas Shale Development In the United States: A Primer (2009).
Types of Proppants

- **Sand** [SG 2.65]
  - White
  - Brown

- **Resin-coated proppant** [SG 2.5 to 3.4]
  - Curable (sand flowback problems)
  - Pre-cured (enhanced strength)

- **Ceramic** [SG 2.5 to 3.6]
  - High strength, sintered bauxite
  - Intermediate strength proppant
  - Lightweight ceramic

- **Lightweight proppants** [SG 1.2 to 1.8]